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MEMORANDUM

TO:	Tom A. Moe, U. S. Steel	REF. NO.:	053103-20
FROM:	Hongze Gao/Steve Harris/ Brian Sandberg/Jon Christofferson, CRA/kf/4	DATE:	July 11, 2013

RE: **Estimate of Time of Travel between the Tailings Basin and the Twin Lakes**
Minntac Tailings Basin
United States Steel Corporation
Mountain Iron, Minnesota

INTRODUCTION

On behalf of United States Steel Corporation (U. S. Steel), Conestoga-Rovers & Associates (CRA) has prepared this Memorandum to present the results of particle tracking simulations to estimate the time of travel between the Tailings Basin and the Twin Lakes (i.e., Little Sandy Lake and Sandy Lake) downstream of U. S. Steel's Minntac Tailings Basin facility located in Mountain Iron, Minnesota (Site). CRA conducted the particle tracking simulations using the existing three-dimensional (3D) groundwater flow model developed for the Site presented in the report entitled, "*Groundwater Flow and Sulfate Transport Modeling Report*" prepared by CRA and dated June 2013 (Modeling Report). The time of travel between the Tailings Basin and the Twin Lakes was requested by the Minnesota Pollution Control Agency (MPCA) as additional information to the Modeling Report expressed in MPCA's letter to U. S. Steel dated May 31, 2013. The travel time estimate is provided separately in this Memorandum as described in the response to MPCA Request 1 in Appendix B of the Modeling Report. This Memorandum presents a brief summary of the approach taken to conduct the particle tracking simulations and the results obtained.

BACKGROUND

Consistent with discussions and meetings between U. S. Steel and the MPCA through October 2012, and set out in the MPCA's November 27, 2012 letter to U. S. Steel, the groundwater flow and sulfate transport modeling includes the following components:

- Extend the model domain south to the Laurentian Divide
- Incorporate the hydrogeologic data obtained in 2012
- Estimate the surface water base flow rate at the outlet of Twin Lakes utilizing flow data from Station 701, precipitation rates, surface water runoff, etc. using the surface water modeling software XPSWMM
- Use the estimated base flow rate at the outlet of the Twin Lakes as an additional calibration target for the updated groundwater flow model calibration

- Use the calibrated groundwater flow model in conjunction with MT3DMS to simulate sulfate migration in groundwater and predict a target Tailings Basin sulfate concentration so that simulated sulfate concentrations in groundwater at the Site boundary would not exceed the groundwater standard of 250 milligrams per Litre (mg/L)

On November 5, 2012, U. S. Steel submitted to the MPCA a proposed modeling approach that incorporated the above components. The MPCA provided approval of the approach on March 22, 2013. CRA, on behalf of U. S. Steel, presented the model development and the modeling results on May 22, 2013 to the MPCA in the MPCA's office in Duluth, Minnesota. Subsequent to the model presentation, the MPCA requested additional information in their letter to U. S. Steel dated May 31, 2013 entitled, "*June 9, 2011 Schedule of Compliance, Target Number presentation/Report*". The Modeling Report was submitted to the MPCA on June 21, 2013 including the additional information requested by the MPCA, except for the MPCA Request 1, as follows:

> *"Time of travel of a water molecule on the fastest path between the tailings basin and Twin Lakes, as taken from the groundwater model. This information should be readily available since it is calculated in the normal building of the model. Also, please provide average or approximate time of travel ranges for water from the basin reaching both the pump-backs and PZ-12."*

As a supplement to the Modeling Report, this Memorandum provides the estimated time of travel between the Tailings Basin and the Twin Lakes to address the MPCA's above request. The full details of the groundwater flow and sulfate transport model development and results are described in the Modeling Report.

SUMMARY OF PARTICLE TRACKING MODELING APPROACH

CRA conducted particle tracking simulations to estimate the time of travel between the Tailings Basin and the Twin Lakes. The particle tracking modeling approach is summarized in general as follows:

- The existing calibrated 3D groundwater flow model developed using MODFLOW-2005, as presented in the Modeling Report, was used as a basis for conducting particle tracking simulations.
- Particle tracking simulations were performed using MODPATH[1] that is a 3D particle tracking program that works in conjunction with MODFLOW-2005. Particle tracking provides a means to evaluate advective groundwater flow pathways and travel time within a simulated groundwater flow field.
- Particle tracking accounts for advective migration only, and is used to evaluate the time of travel at the rate of groundwater movement through the porous media (i.e., time of travel of a water molecule). It does not account for any other processes, such as adsorption, dispersion, and dilution from groundwater mixing that can reduce, or attenuate, groundwater concentrations.

Particles were released at the northeast edge of the Tailings Basin pool for Cell #2 located closest to the Twin Lakes upgradient of piezometer nest PZ-5S/D, as presented on Figure 1. The particles were released at the bottom of Model Layer 1, which corresponds to the approximate bottom of Tailings Basin pool, as

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[1] Pollock, D.W., 1994. User's Guide for MODPATH/MODPATH PLOT, Version 3: A Particle Tracking Post Processing Package for MODFLOW, the U. S. Geological Survey Finite Difference Ground Water Flow Model, United States Geological Survey Open File Report 94 464, Reston, Virginia.

represented in the groundwater flow model. The pathways of these particles were predicted forward in time through the steady-state simulated groundwater flow field for the calibrated model. The particle pathways were simulated using the effective porosity values determined through the approximate calibration of the sulfate transport model to historically observed sulfate concentrations in groundwater, as presented in Table 7.1 of the Modeling Report.

ESTIMATED TIME OF TRAVEL

The time of travel was estimated under historical groundwater flow conditions (i.e., prior to installing the seep collection and return [SC & R] system sheet-pile walls) and under current conditions (with the SC & R system sheet-pile walls in place). Steady-state groundwater flow conditions were simulated to represent the long-term stabilized average groundwater flow conditions, and the steady-state flow field was used to conduct the particle tracking simulations.

Figure 1 shows the simulated particle pathlines and travel times under historical conditions (i.e., prior to installing the SC & R system sheet-pile walls). The particle pathlines are colored based on whether they pass through the shallow overburden (orange) or deep overburden (green) as they move away from their release locations. Arrows are posted along the pathline for each particle at a 5-year interval.

Figure 1 demonstrates that particles released in Cell #2 do not migrate to the Twin Lakes directly. Rather, the particles pass under the perimeter dike in the deep overburden, move upwards into the shallow overburden, and then move laterally to discharge to the drain boundary conditions specified in the model to represent the wetland area east of piezometer nest PZ-12S/I/D, which is located between the Twin Lakes and the Cell #2. Shallow groundwater discharge to the wetland area is consistent with the observed persistence of the wetland, and upward vertical hydraulic gradients observed at piezometer nest PZ-12S/I/D (see Table 2.1 of the Modeling Report). The northern most particles discharge to the drain boundary conditions specified to represent seepage taking place at the toe of the perimeter dike that is now being captured by the SC & R system. These particles discharge in less than 5 years. Particles reaching the wetland area do so in approximately 10 to 23 years. These particles reach the location of the SC & R system (see the sheet-pile wall location on Figure 2) and piezometer nest PZ-12S/I/D in approximately 8 to 14 years, and 9 to 22 years, respectively. Groundwater discharging to the wetland area would reach the Twin Lakes through surface water flow processes.

Figure 2 shows the simulated particle pathlines and travel times under current conditions (i.e., with the SC & R system sheet-pile walls in place). The simulated particle pathlines are similar to that occurring for the historical conditions, except that particles reaching the sheet-pile wall move downward from the shallow overburden into the deep overburden to pass under the sheet-pile wall, which extends through the shallow overburden only. The particles then move upwards back into the shallow overburden before discharging to the wetland area. Particles reach the location of the SC & R system in approximately 8 to 14 years, as occurs under historical conditions. Particles reaching the wetland area do so in approximately 10 to 25 years, and these particles reach piezometer nest PZ-12S/I/D in approximately 9 to 24 years. The sheet-pile wall moderately increases the travel time to piezometer nest PZ-12S/I/D and the wetland area compared to that occurring under historical conditions.

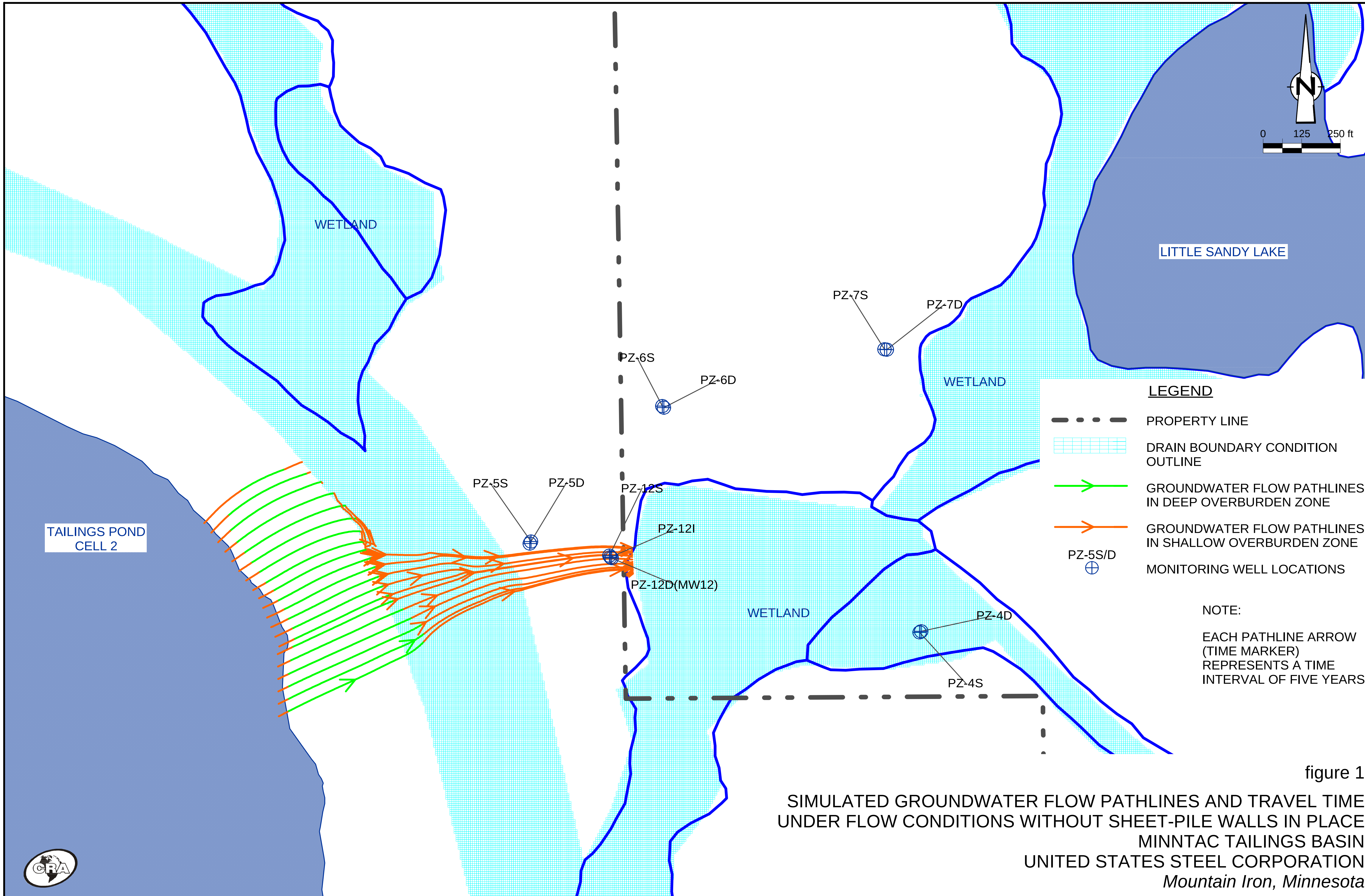

figure 1

SIMULATED GROUNDWATER FLOW PATHLINES AND TRAVEL TIME
UNDER FLOW CONDITIONS WITHOUT SHEET-PILE WALLS IN PLACE
MINNTAC TAILINGS BASIN
UNITED STATES STEEL CORPORATION
Mountain Iron, Minnesota

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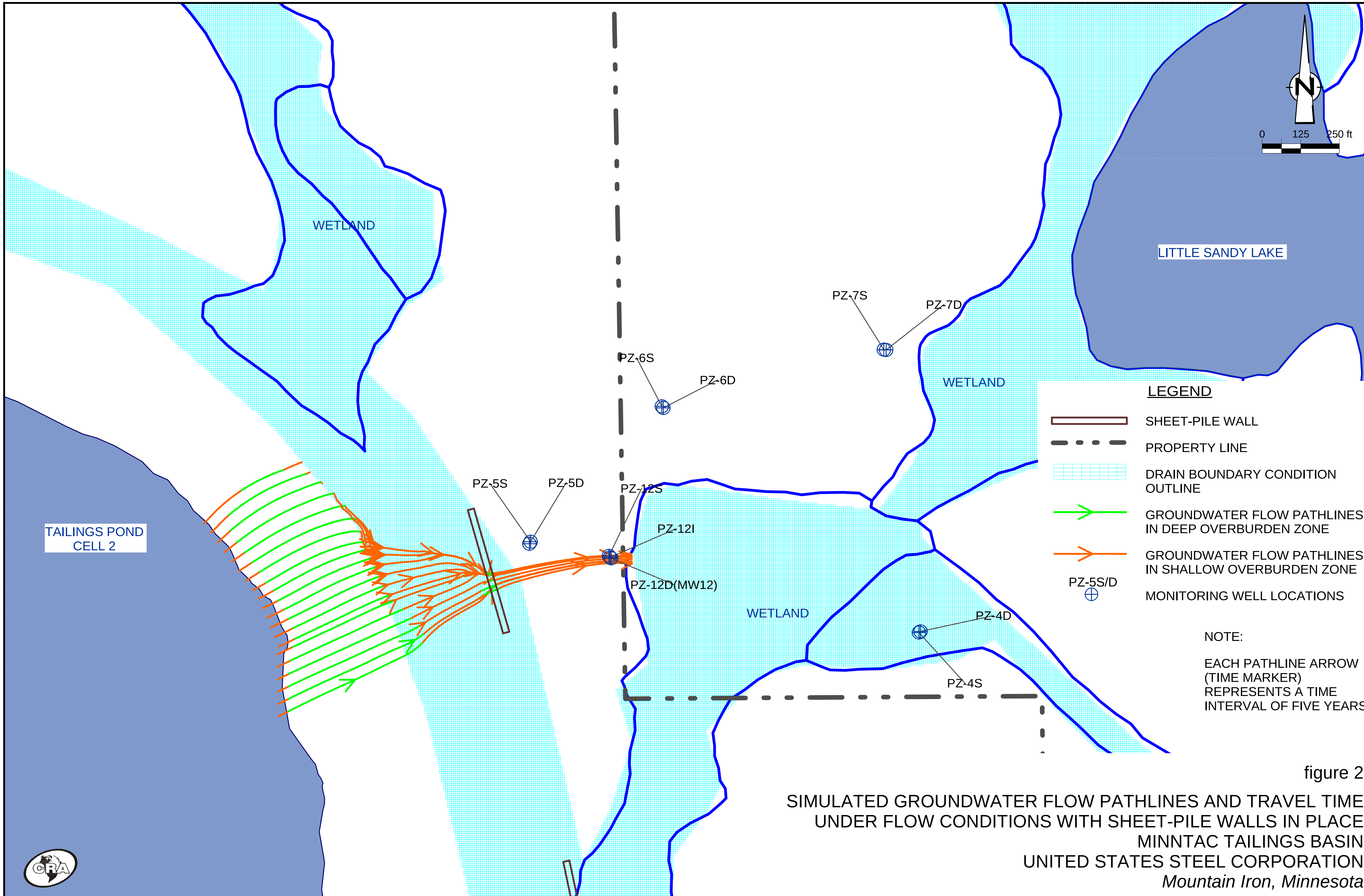

figure 2

SIMULATED GROUNDWATER FLOW PATHLINES AND TRAVEL TIME
UNDER FLOW CONDITIONS WITH SHEET-PILE WALLS IN PLACE
MINNTAC TAILINGS BASIN
UNITED STATES STEEL CORPORATION
Mountain Iron, Minnesota

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